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# **INTRODUCTION TO RTM WORKSTATION**

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*Jeffrey M. Lawrence*

*Mathieu Devillard*

*Peter Friede*

*Dr. Suresh G. Advani*

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# Outline

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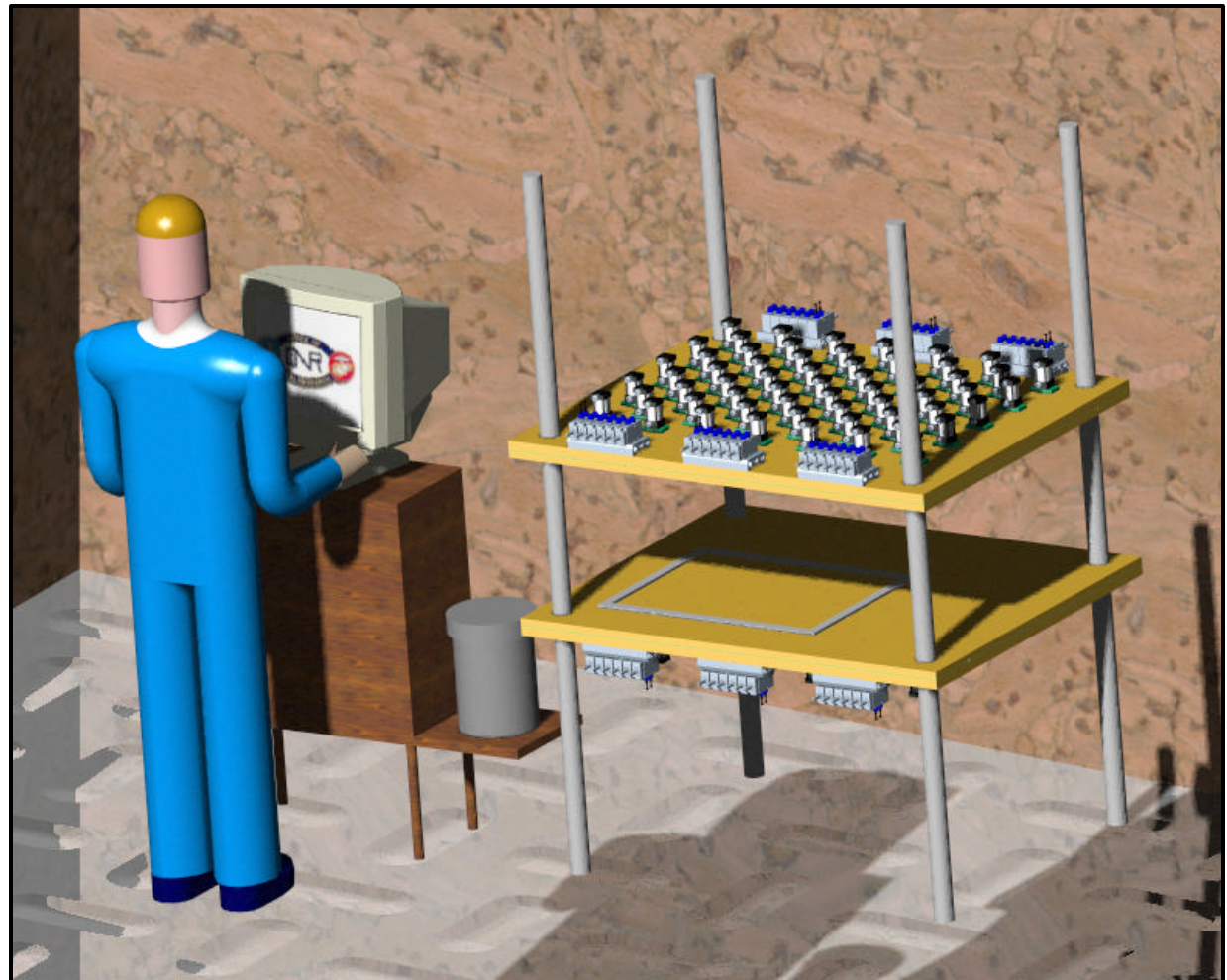


- 1. Objective / Motivation**
- 2. Previous design concept**
- 3. Current lab scale implementation**
- 4. On-line mixing of resin**
- 5. Extension**

# Objective

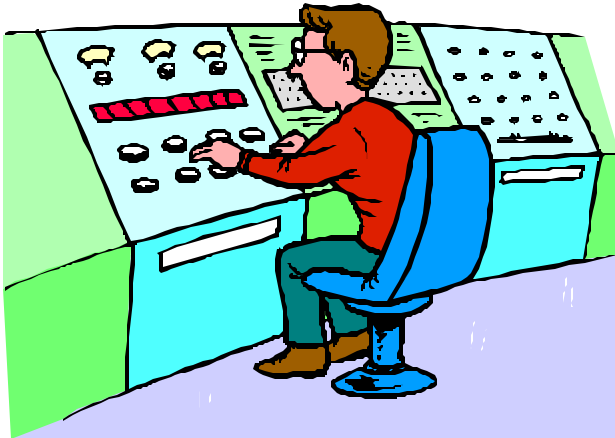
The objective is to build a modular RTM Workstation featuring:

- ◆ Modularity in part geometry
- ◆ Reduced prototype development costs
- ◆ Automated control
- ◆ Integrated system



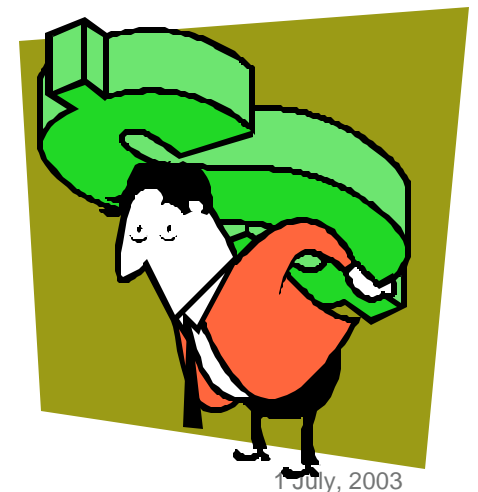


# Motivation



... as well as a desire to reduce tooling costs and turnaround times, which are a major factor in the expense of RTM.

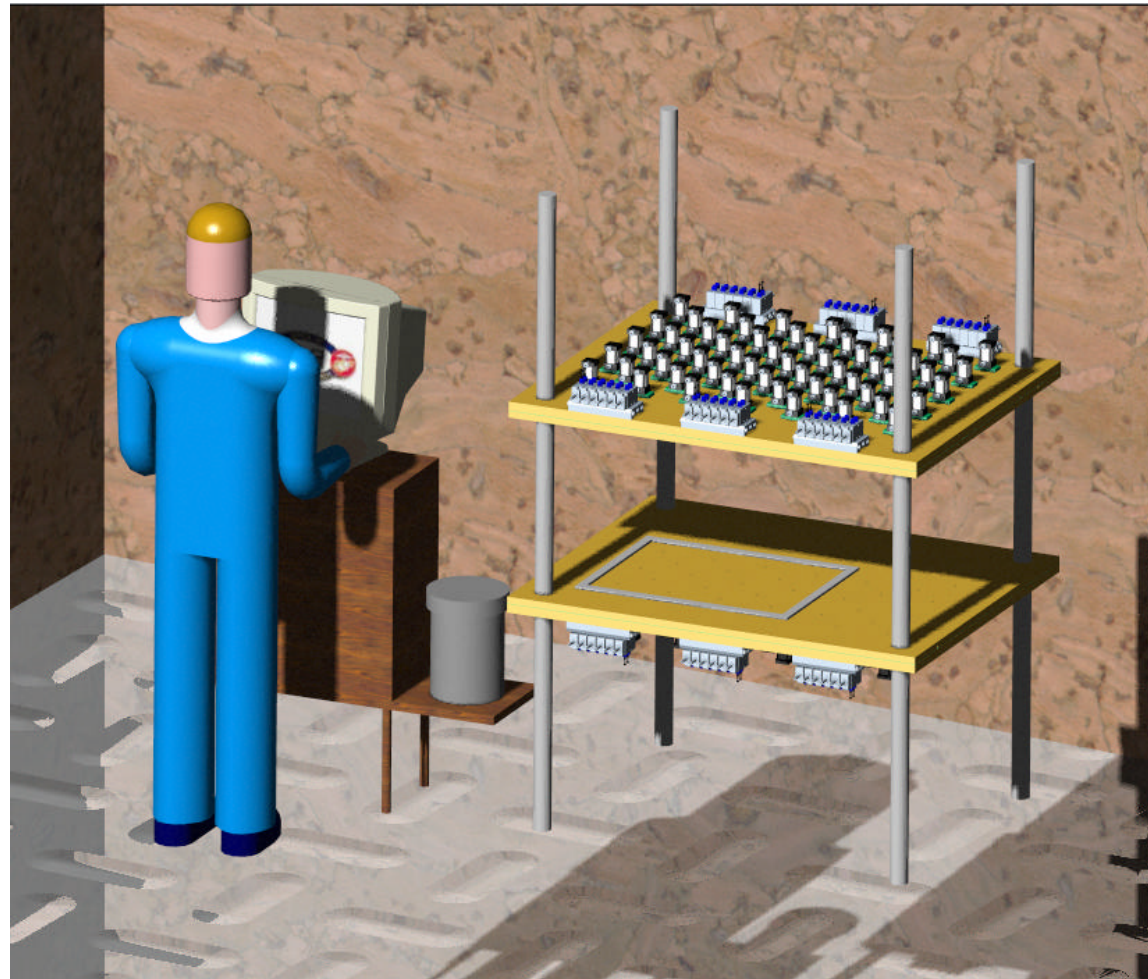
There is a need to have better control of the filling stage to ensure part quality and increase yield of production ...



# Part-to-Part Operation



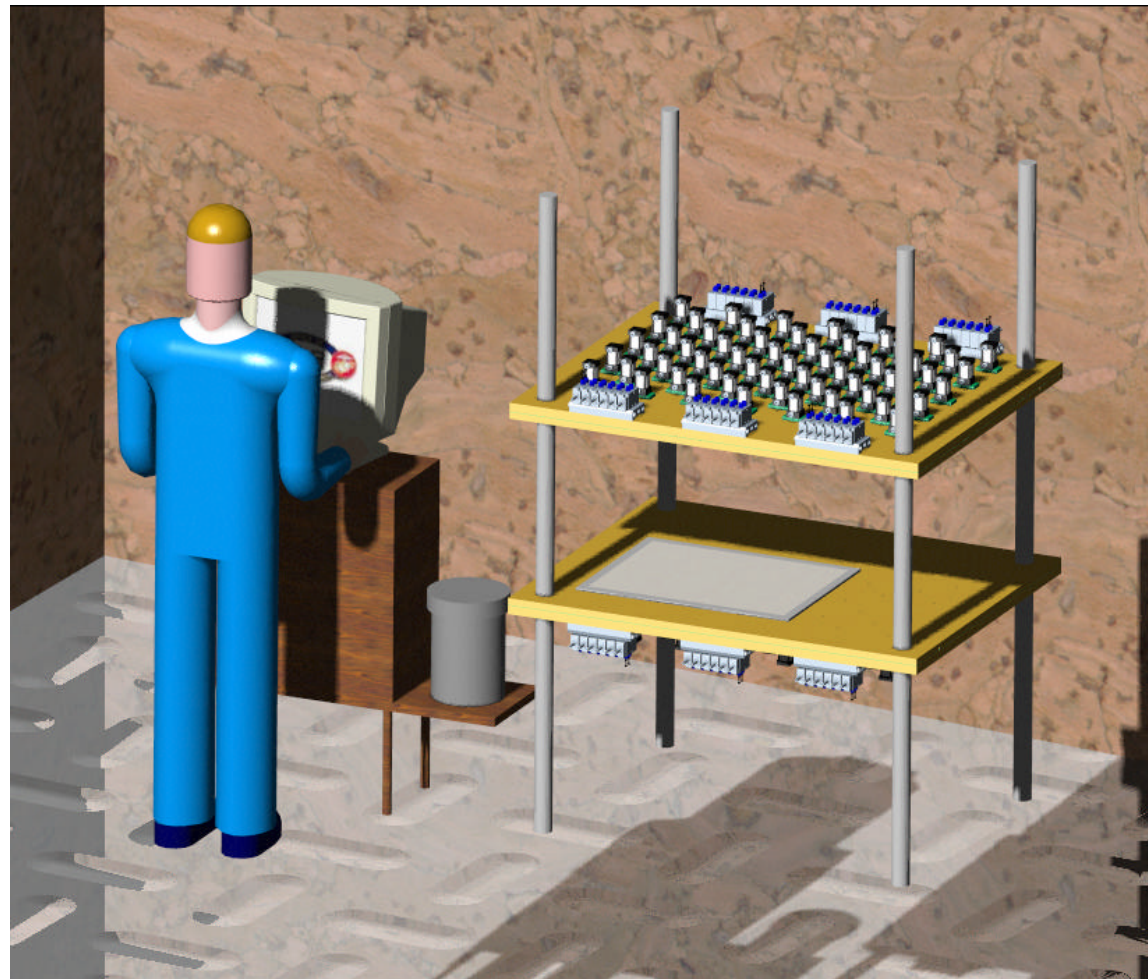
The mold system is ready to start with the first part



# Part-to-Part Operation



The preform is loaded into the mold

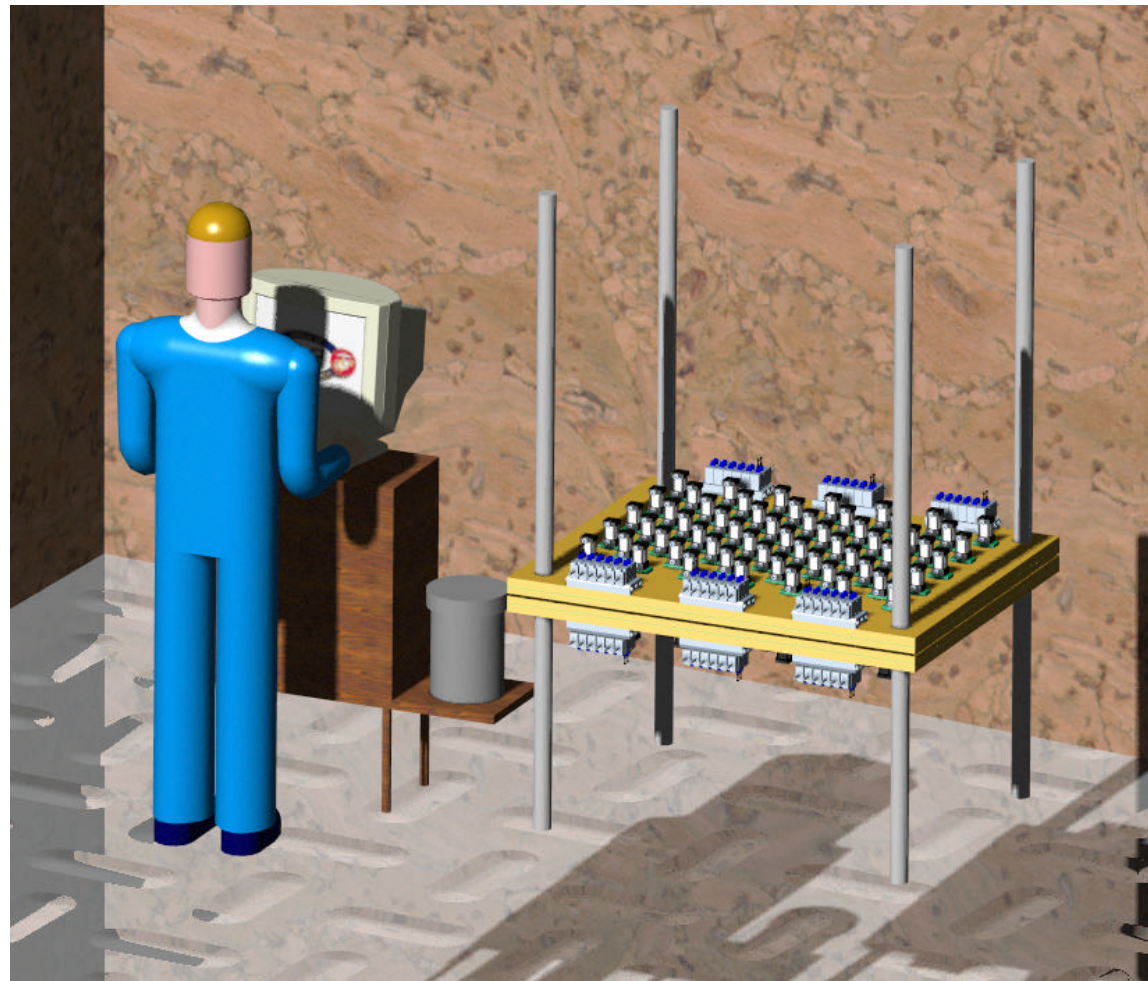




# Part-to-Part Operation



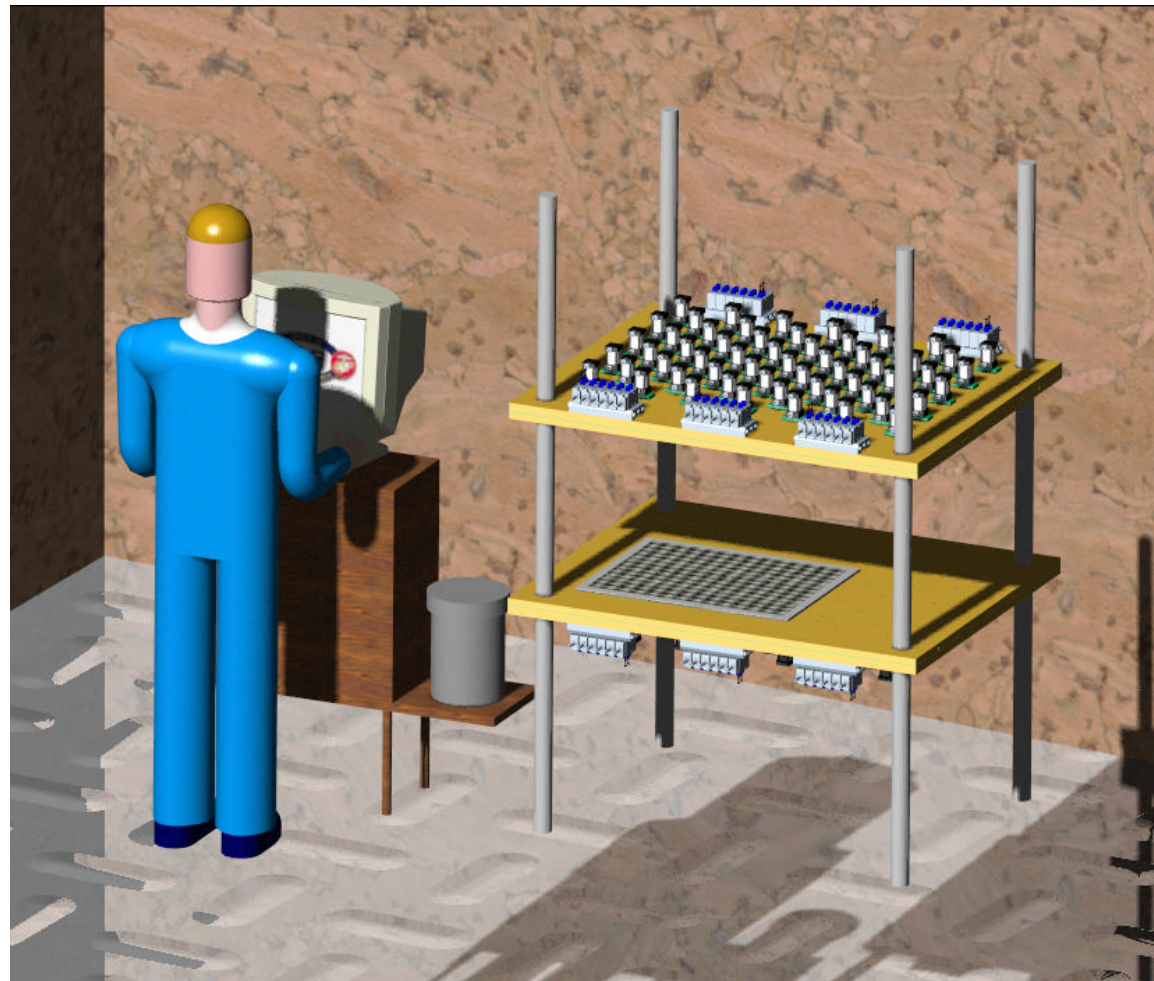
The mold is closed and sealed, the resin is injected and allowed to cure



# Part-to-Part Operation



The mold is open, revealing the filled part

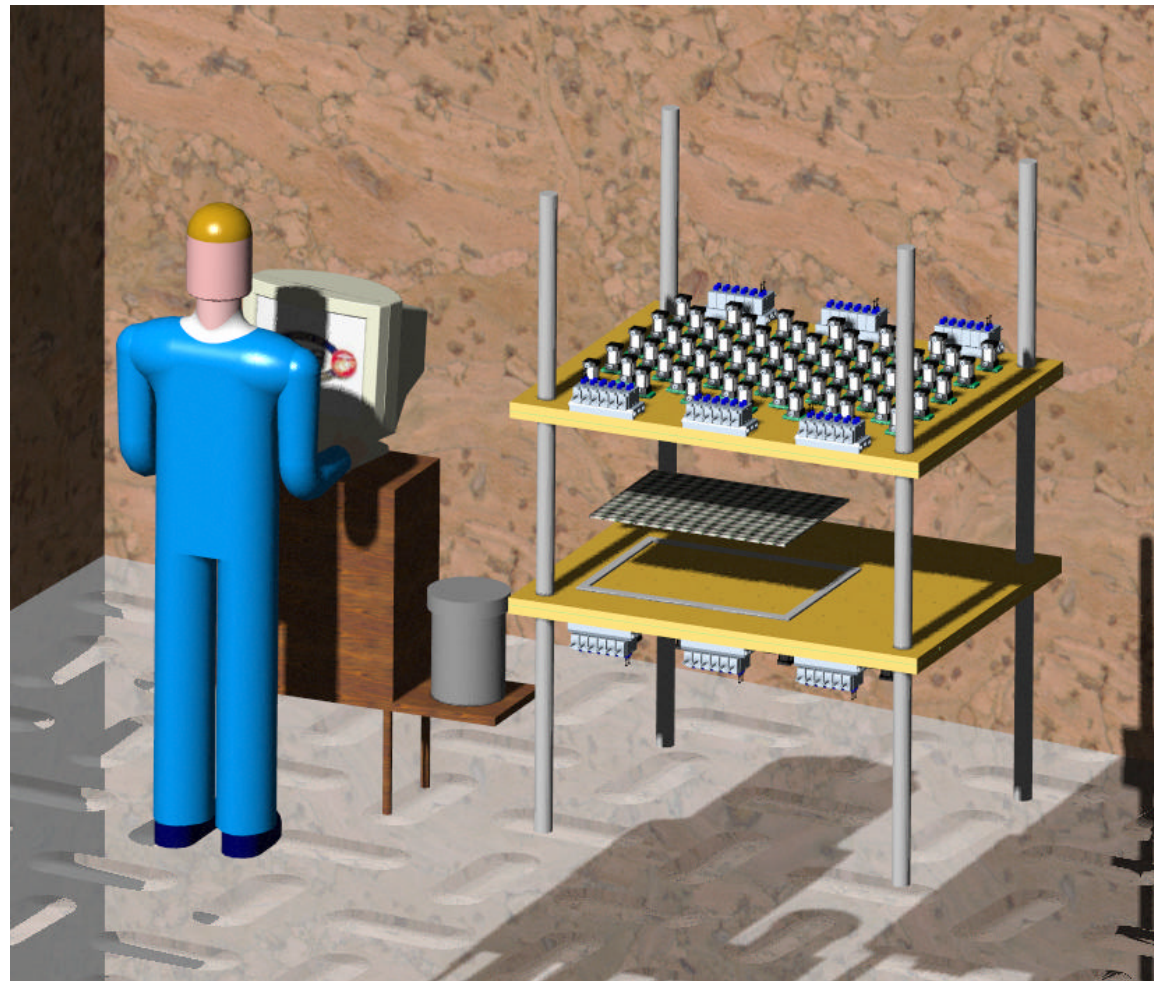




# Part-to-Part Operation



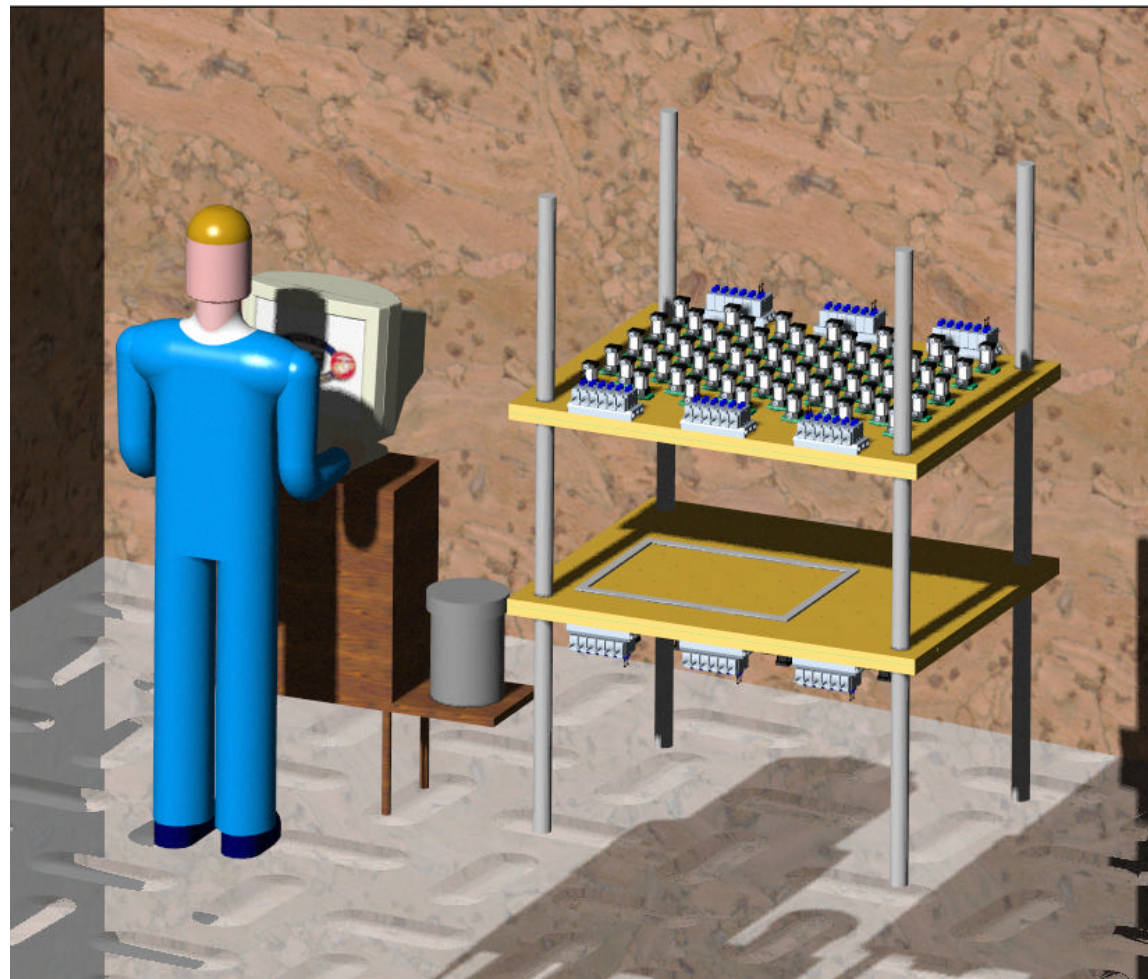
The part is  
demolded ...



# Part-to-Part Operation



... and  
removed from  
the mold

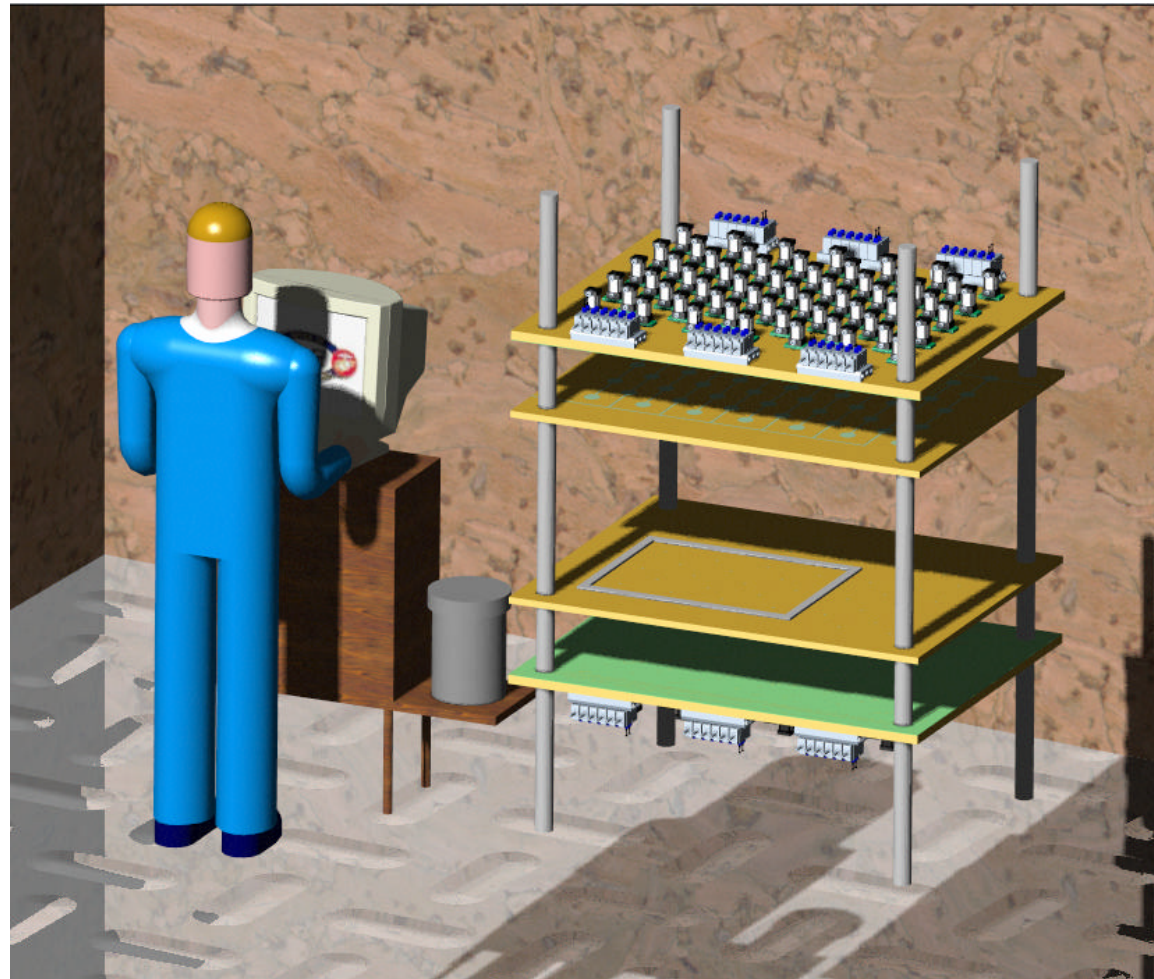




# Part-to-Part Operation



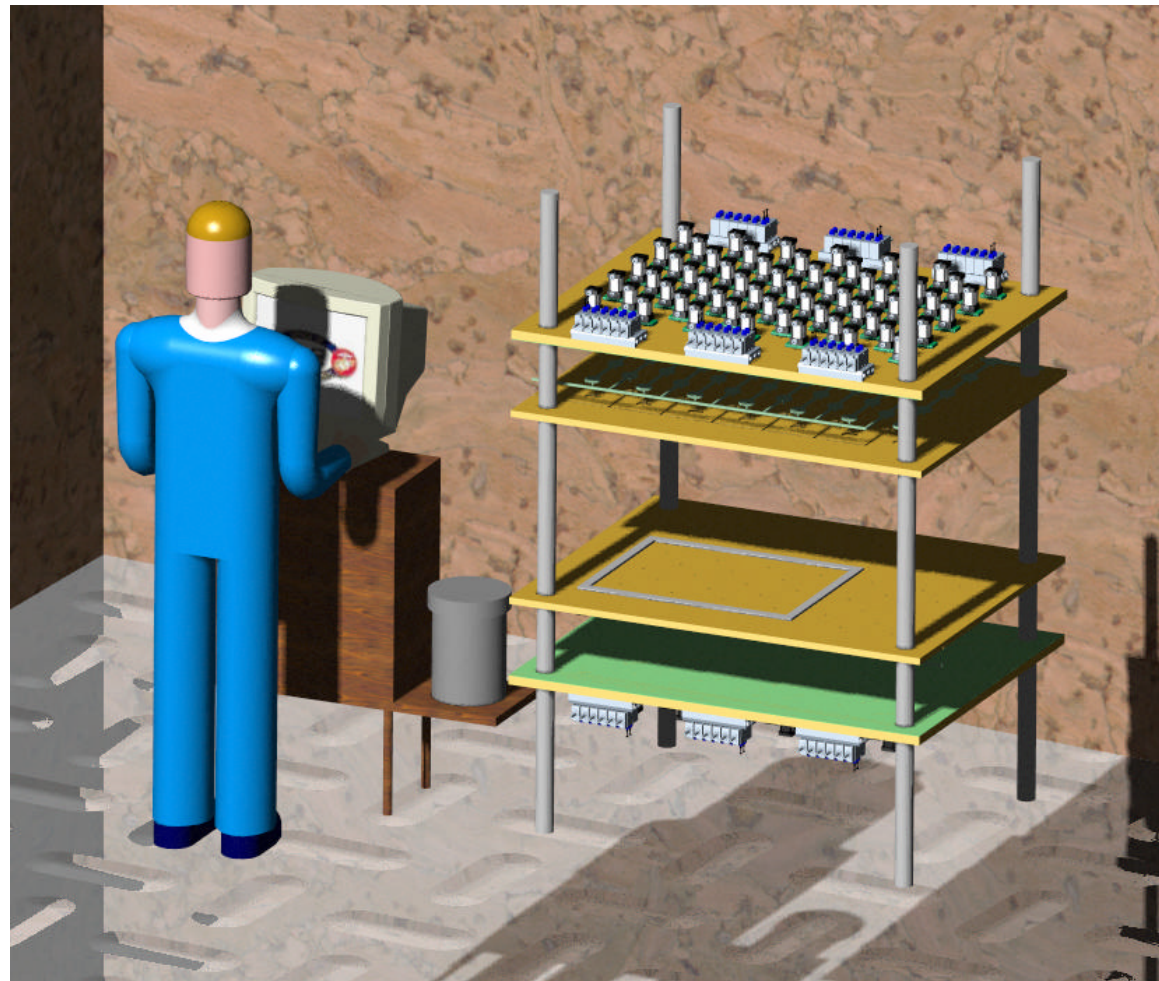
The plate systems are separated revealing the resin chunks



# Part-to-Part Operation



The resin  
chunks are  
demolded ...

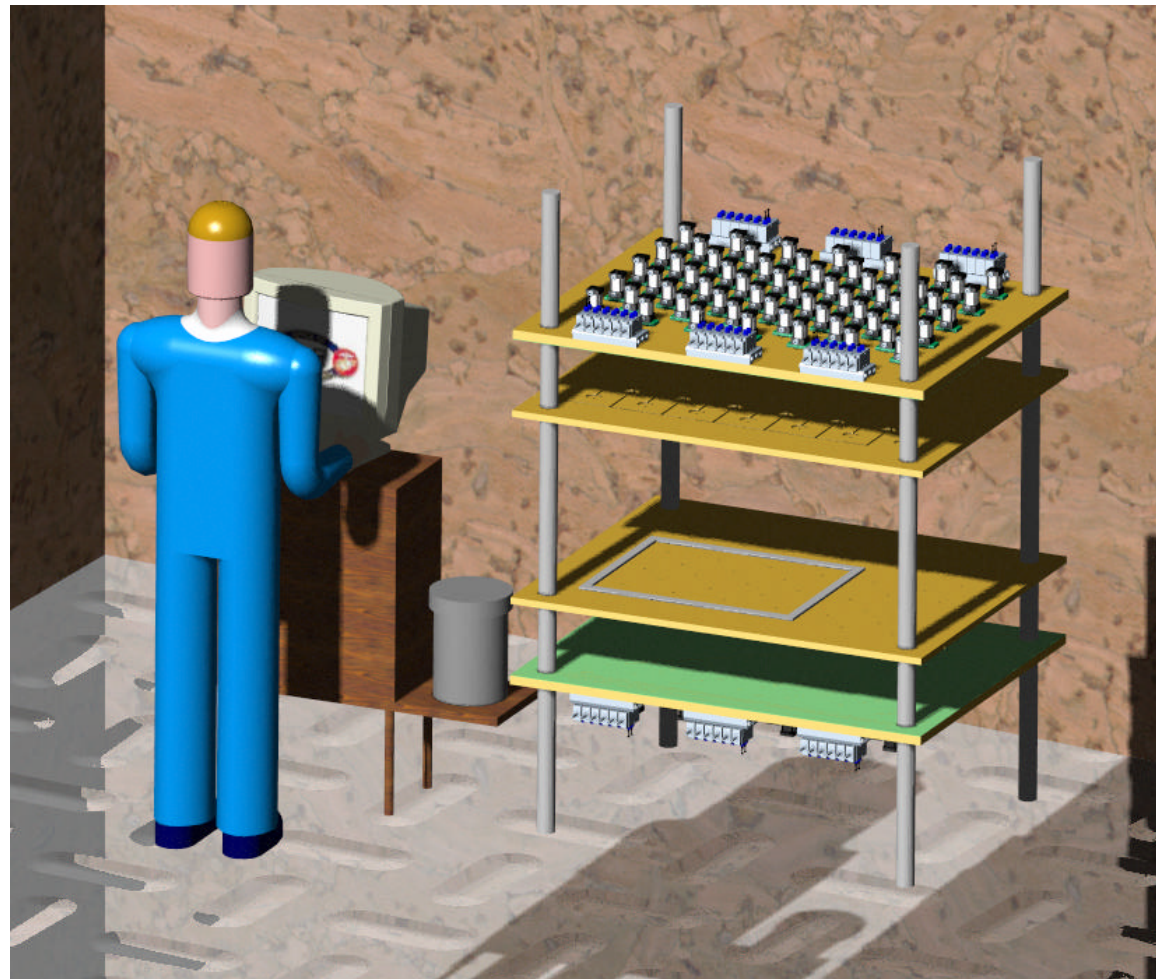




# Part-to-Part Operation



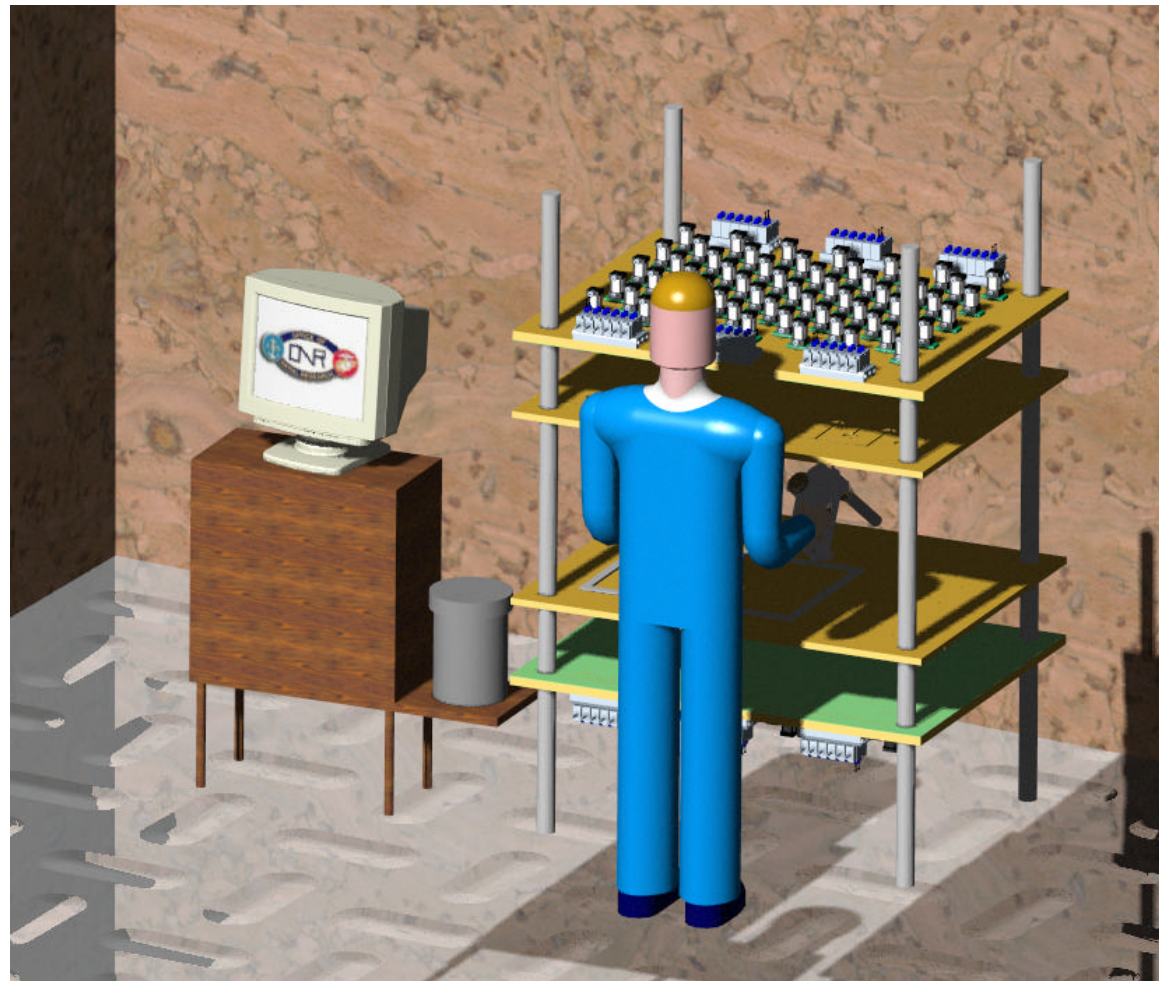
... and  
removed from  
the mold



# Part-to-Part Operation



Finally, the mold is prepared for the next part by applying release agent



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# RTM Workstation

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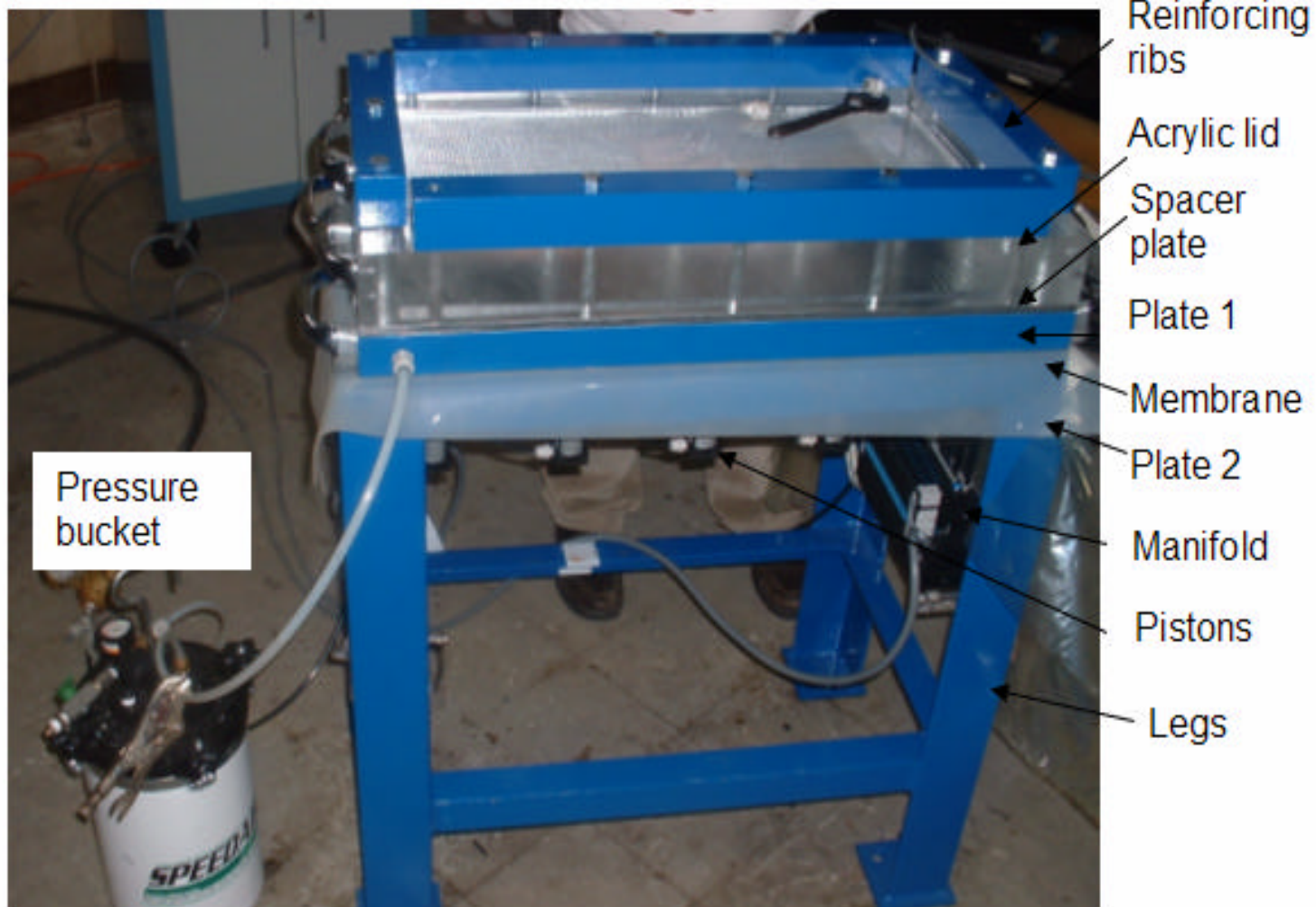


**To test the entire system, it was decided to build a mid-scale system. The details are as follows:**

- **No hydraulics to open and close plates**
- **Single sided mold, with gates/vents/sensors on bottom only**
- **Acrylic lid on top for visualization**
- **1' x 2' working area for parts**
- **20 psi limit inside mold**



# RTM Workstation



# Control Center

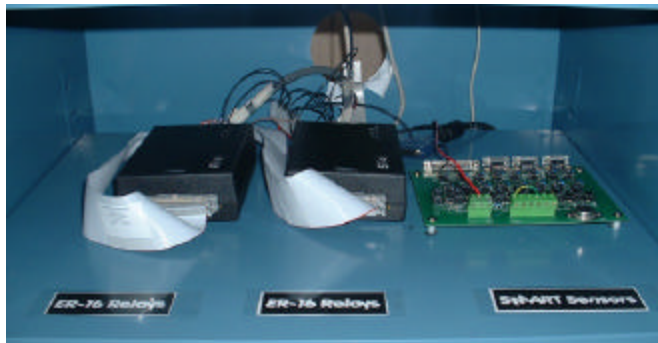


- neatly containing all data acquisition components





# Control Center



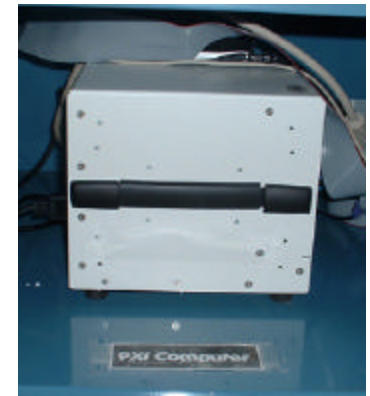
## ***Shelf 1:***

- ER-16 Relay Box
- ER-16 Relay Box
- SMART Sensor card



## ***Shelf 2:***

- 5V Power Supply
- 24V Power Supply
- Power Supply Switch



## ***Shelf 3:***

- PXI Computer

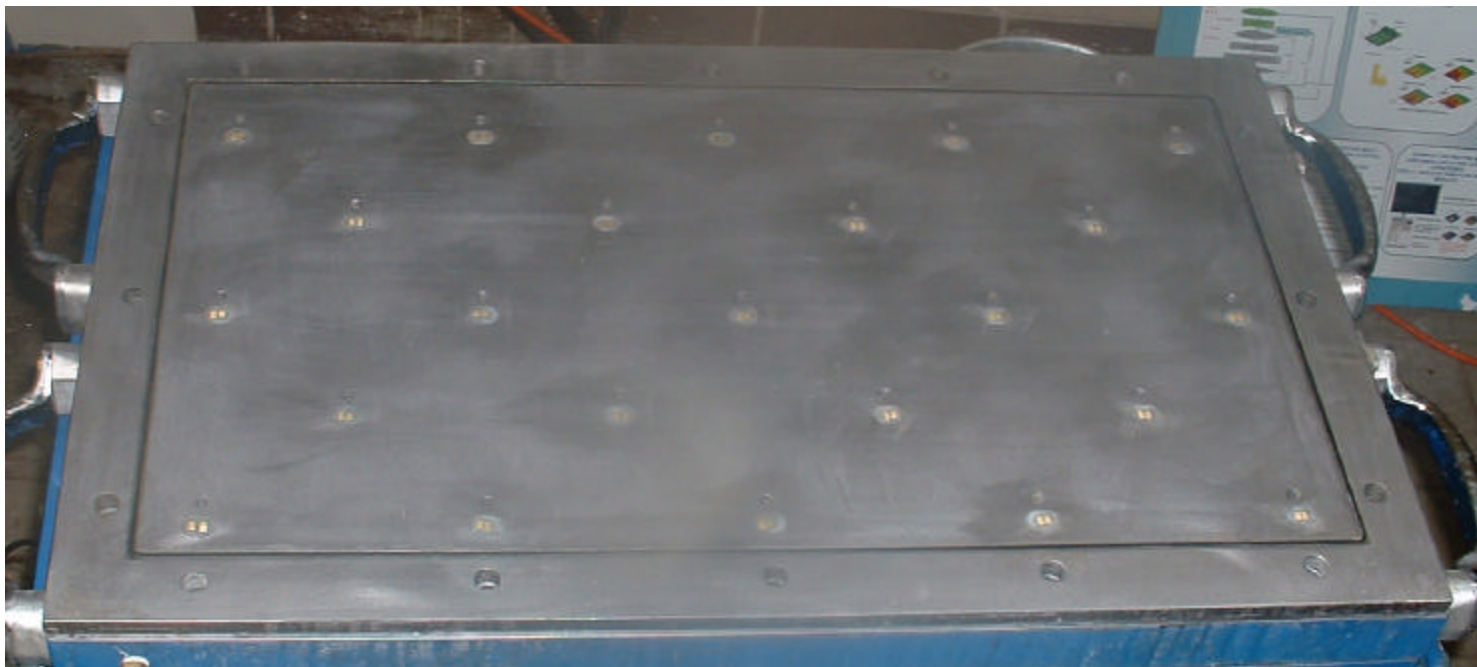
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# Sensor Plate

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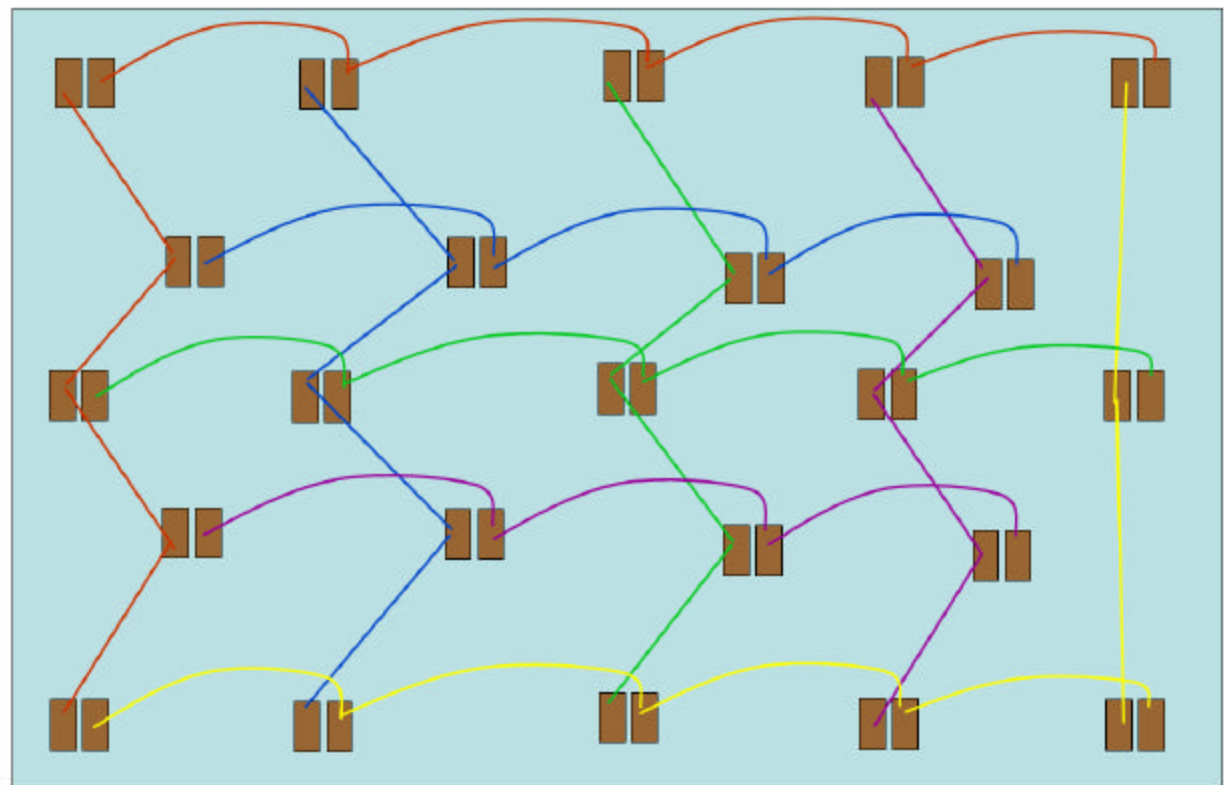
The electric sensors detect the arrival of the flowing fluid. They are mold imbedded to allow for ease of use and minimal effect on the part surface.



# Sensor Diagram for Multiplexing



Multiplexing  
allows an array  
of 23 sensors to  
be realized with  
only 10 wires (5  
excitation / 5  
sensing)



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# Manufacture of Different Geometries

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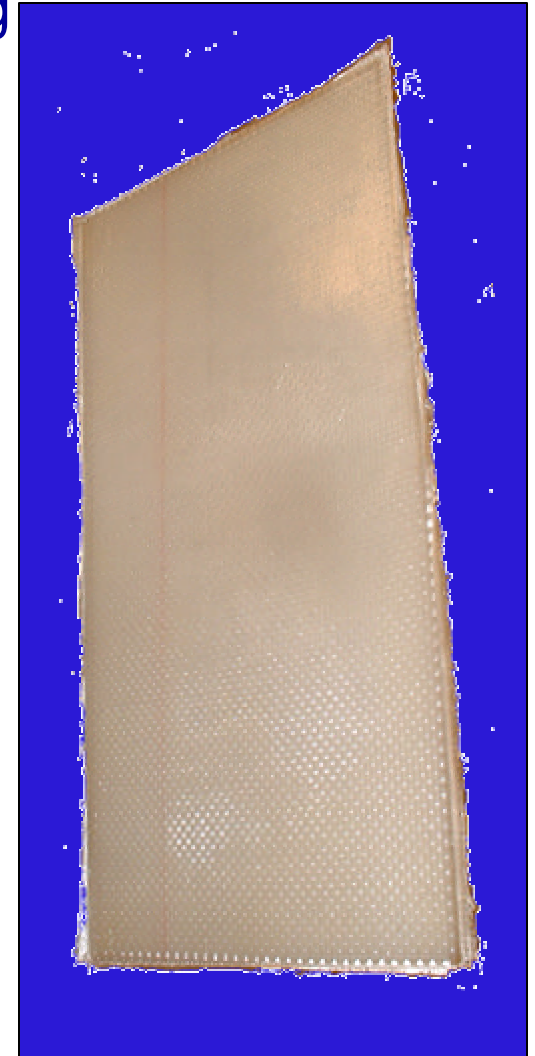
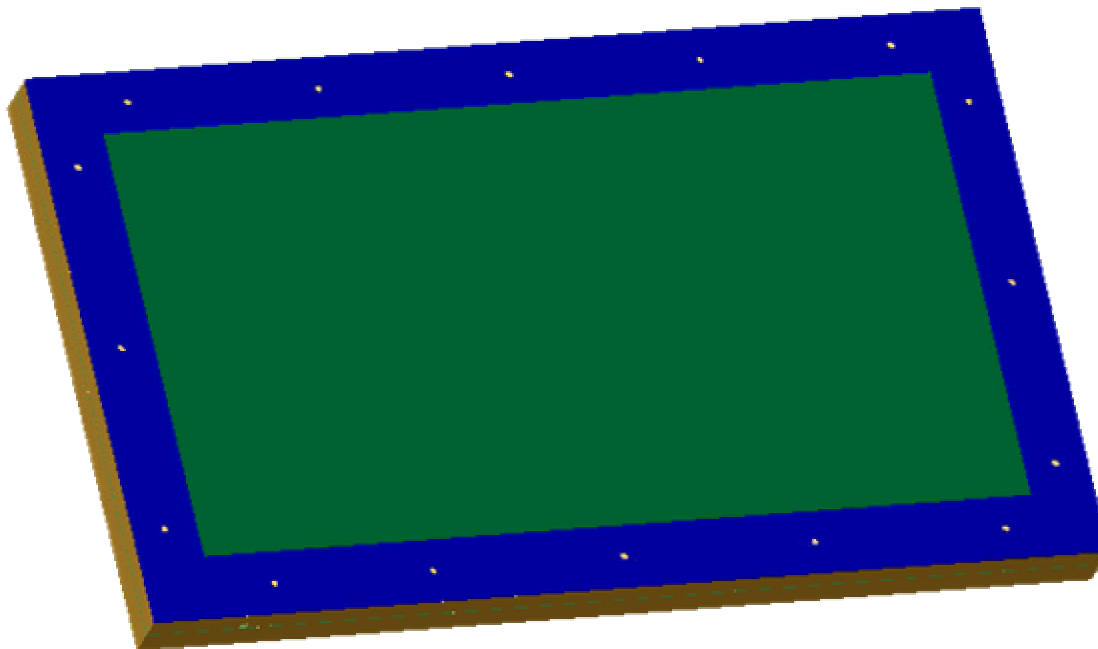
Once the workstation was built, the ability of the mold to be modular and to produce different geometries was tested.



# First Geometry



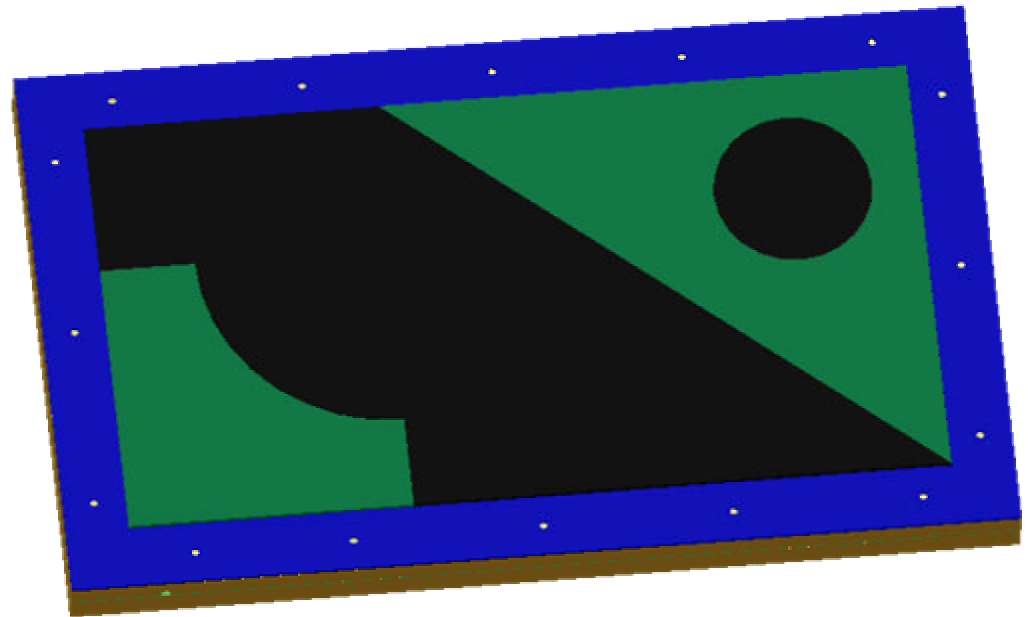
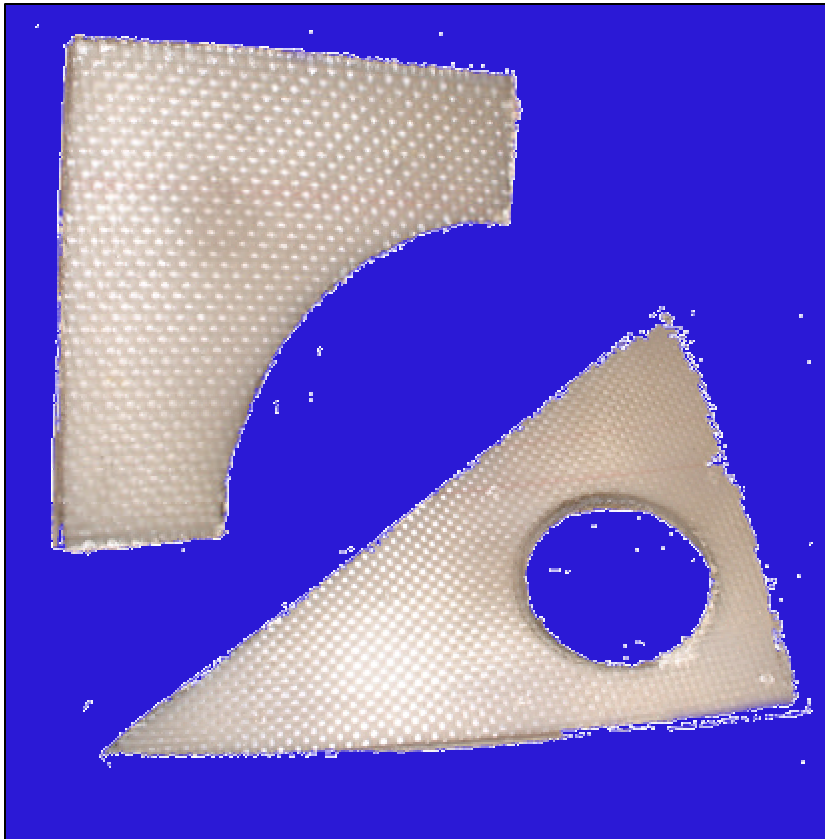
The first geometry was a simple rectangle, taking advantage of the full 1' x 2' area of the mold.



# Second and Third Geometry



The second and third geometries were used to demonstrate the ability to manufacture multiple parts at the same time.



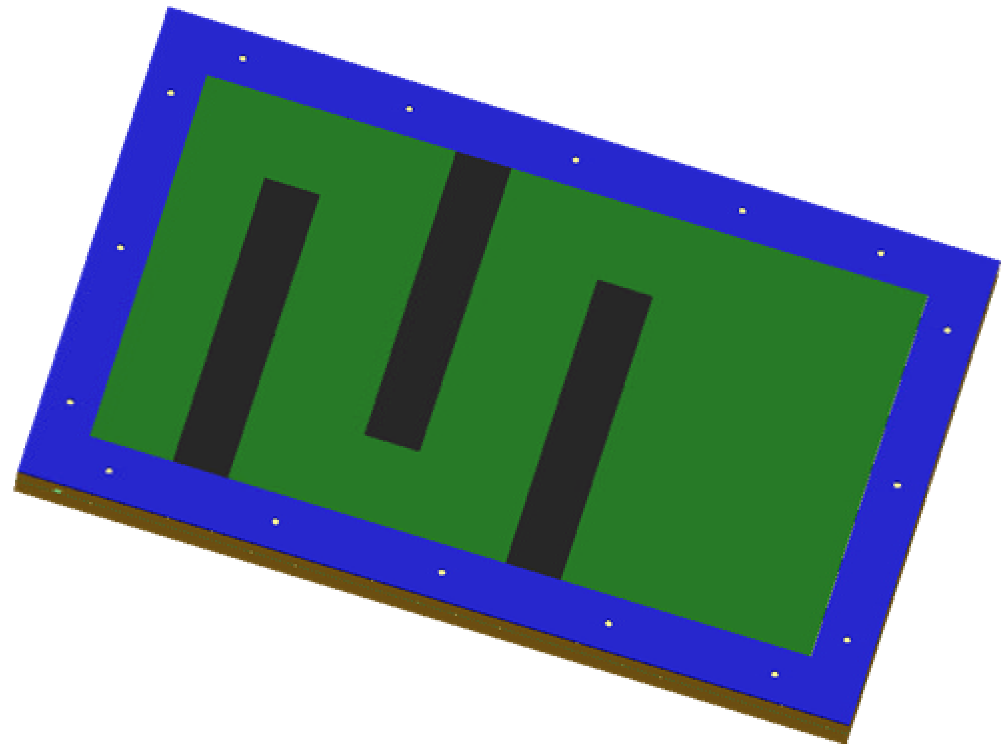
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# Fourth Geometry

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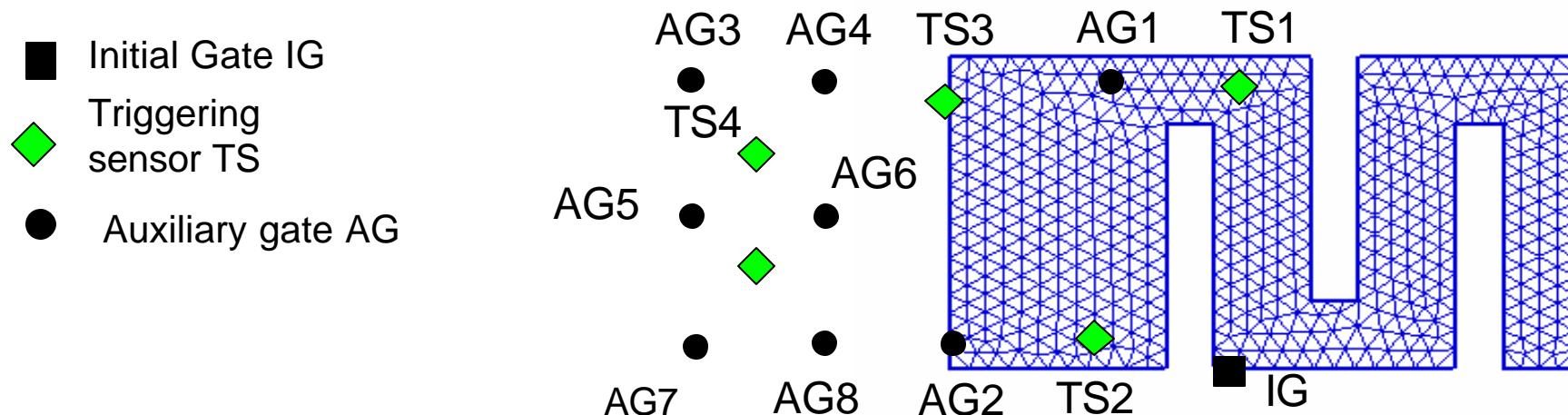


The fourth geometry selected was used to demonstrate the controllability of the workstation. A sequential injection was used to ensure that the entire part could be filled quickly





# Sequential Injection Scheme

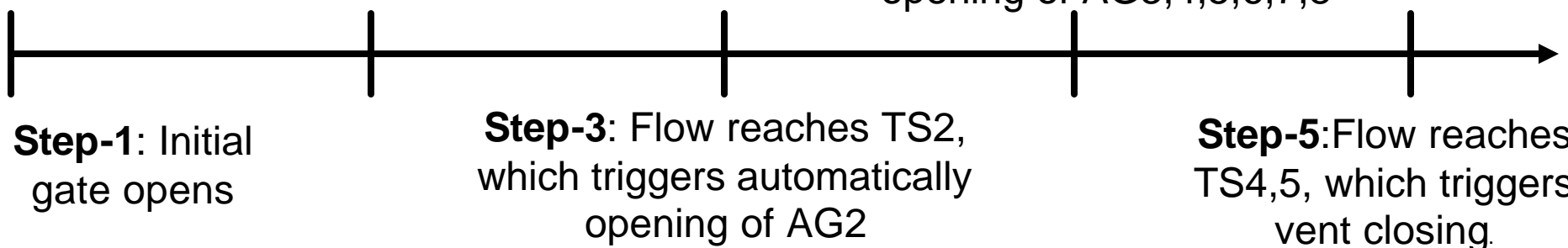


## Step-2:

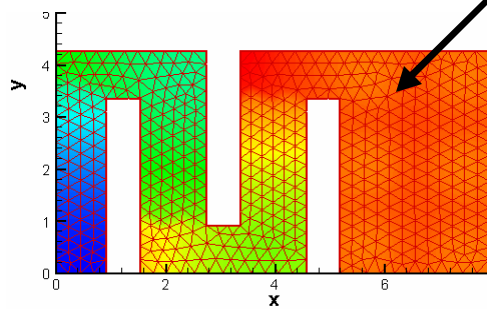
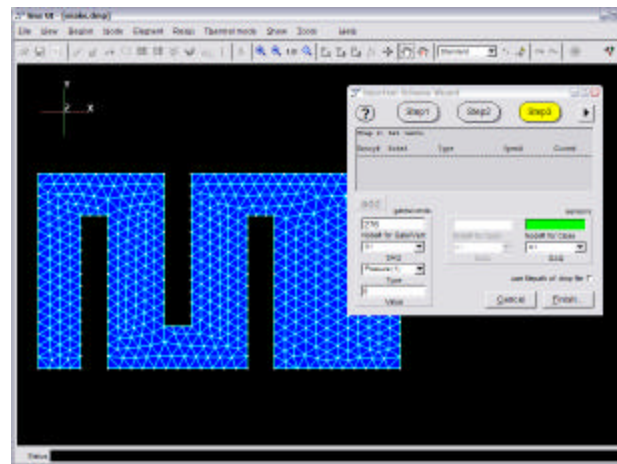
Flow reaches TS1, which triggers automatically opening of AG1 and closing IG

## Step-4:

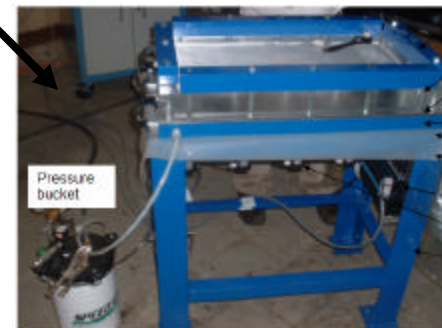
Flow reaches TS3, which triggers automatically opening of AG3,4,5,6,7,8



# Sequential Injection Wizard

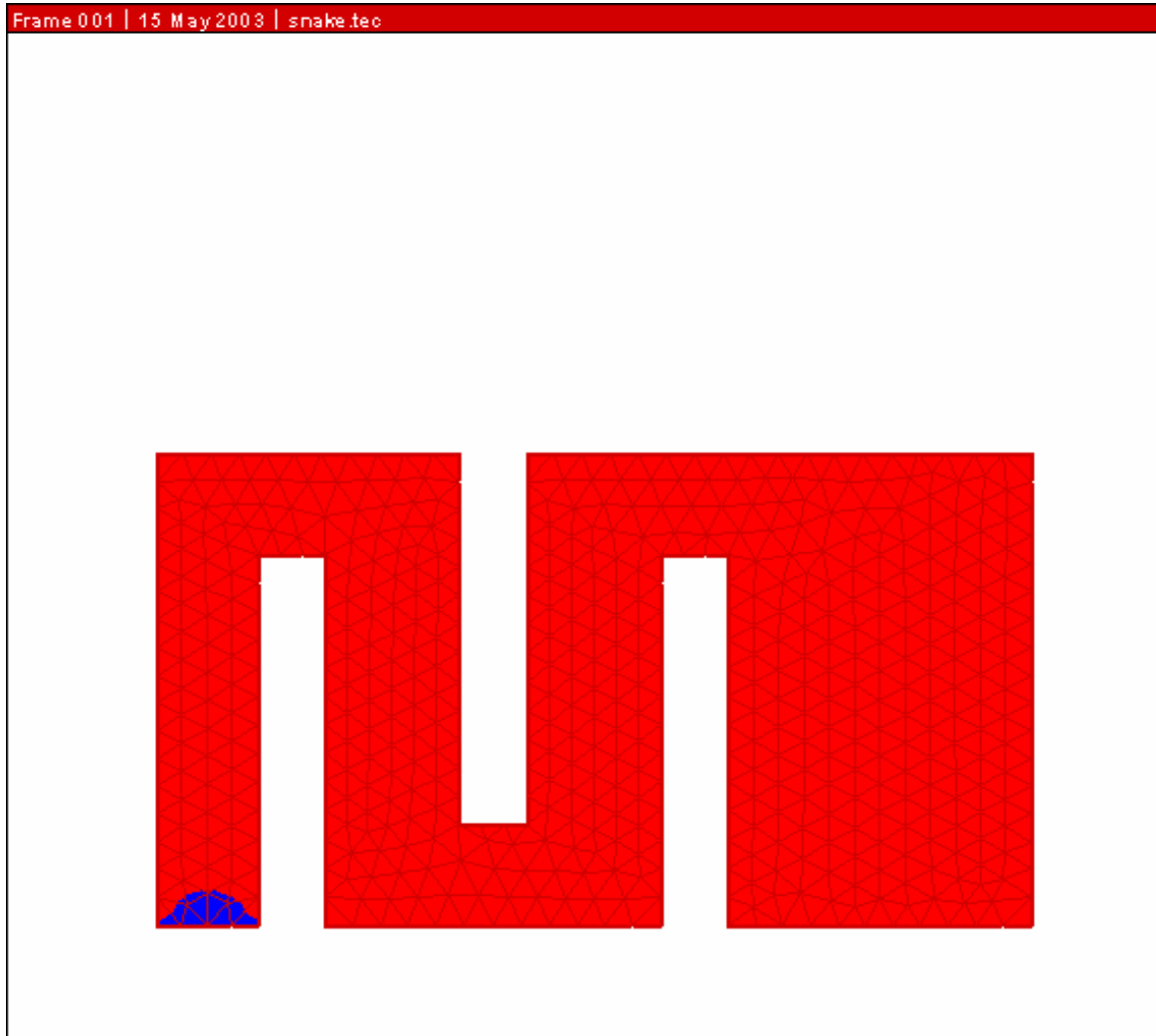


**Simulation**

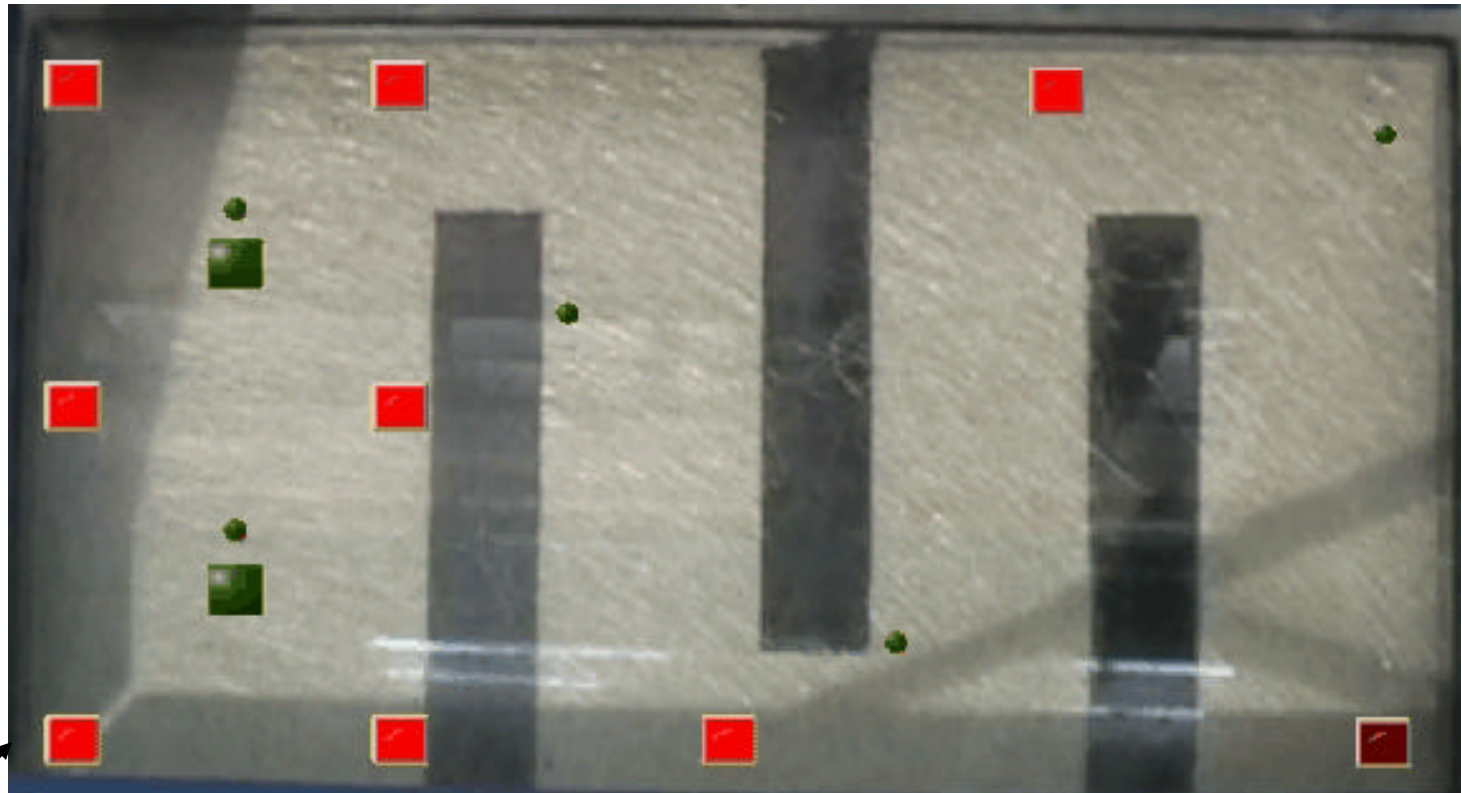


**Implementation fully automated**

# Simulation Results



# Sequential Injection Experiment



Open gate



Open vent



Untriggered sensor



Closed gate



Closed vent



Triggered sensor

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# Resultant Part

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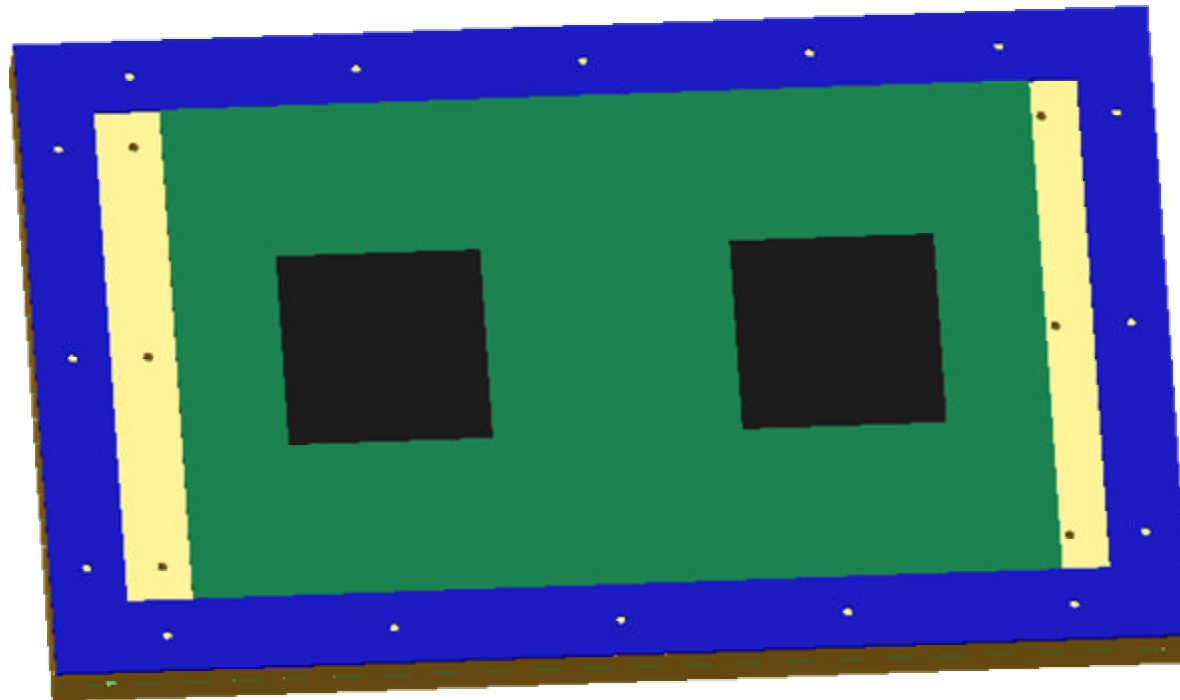
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# Fifth Geometry

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The fifth geometry was selected to demonstrate the integration of SLIC with the RTM Workstation for sensing and control of the filling



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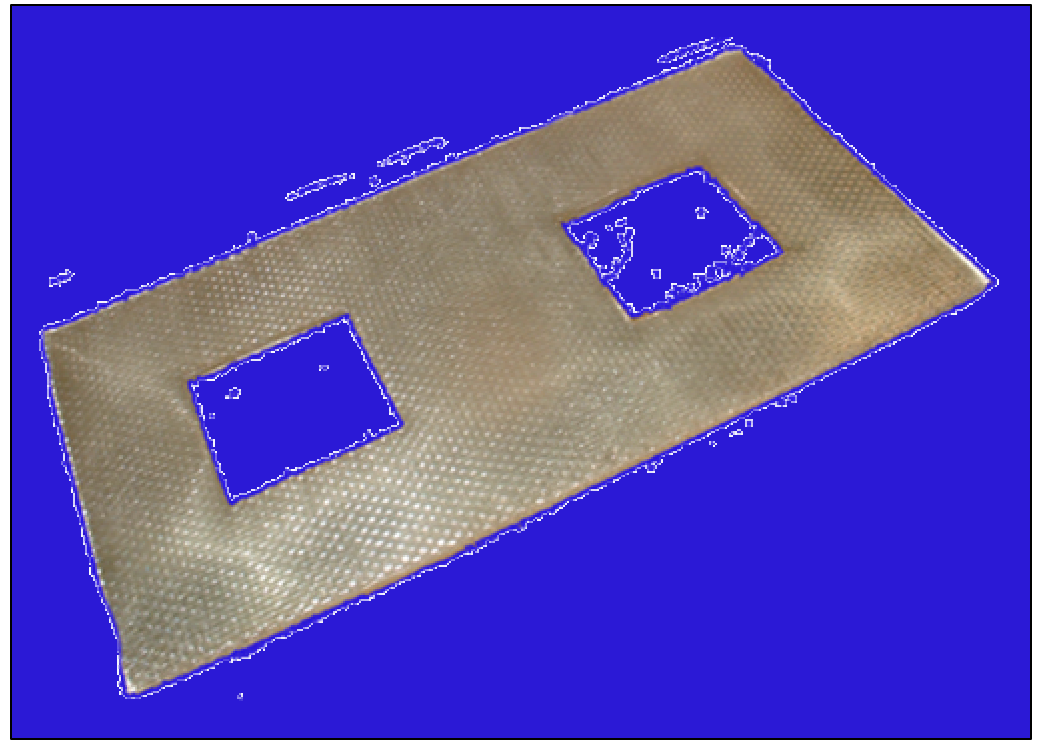
# SLIC for New Geometry

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The potential gate/vent/sensor locations were input into SLIC and the program was run to generate the mode detection and control action files.

Work is ongoing to experimentally validate these results.

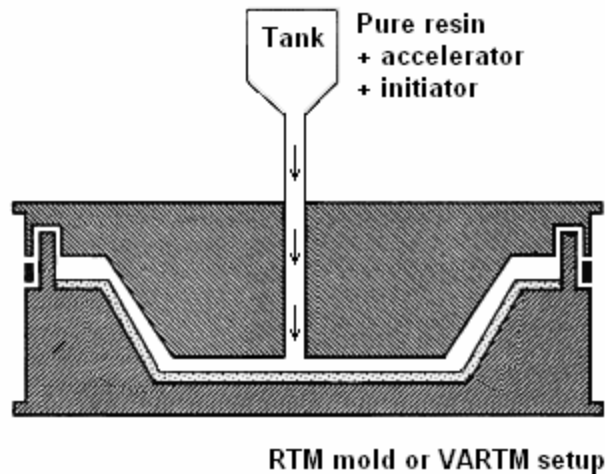




# On-Line Mixing Studies of Resin and Curing Agents

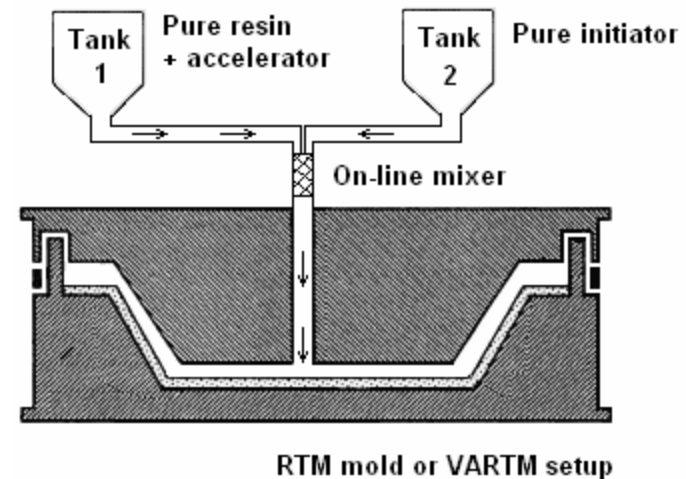


## Standard injection setup



- Mixture has a short time life
- Unused resin is waste
- Discontinuous process

## On-line mixing injection setup



- Both components are stable when apart
- Appropriate system for process automation
- No degasification required
- Cost effective
- Continuous process possibility

# Goals



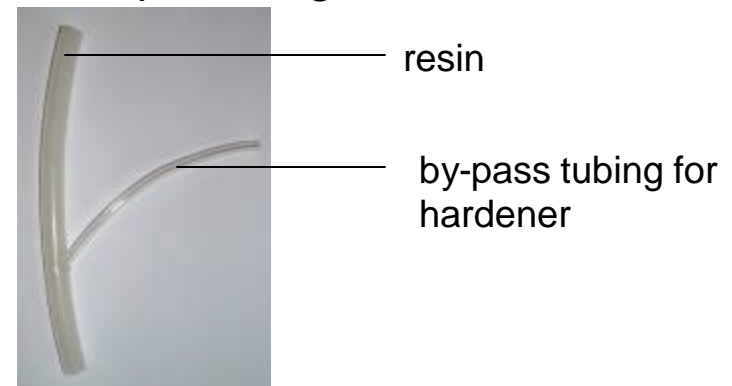
1. Develop an **AUTOMATED SYSTEM** providing a **varying mixing ratio** and hence curing reaction kinetic by progressively increasing hardener concentration during injection

**Approach:** use a computer controlled Injector pump



2. Develop a **SIMPLE AND LOW COST SETUP** providing a **constant mixing ratio** during injection.

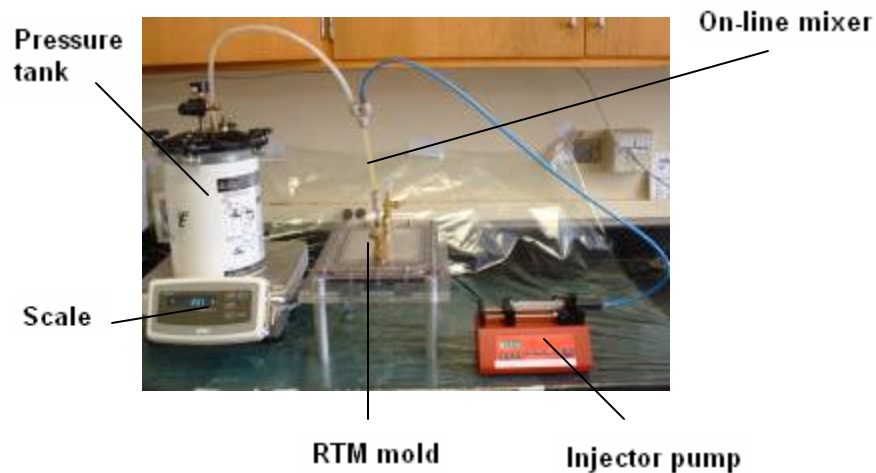
**Approach:** use by-pass tubing for hardener



# Experimental Setup

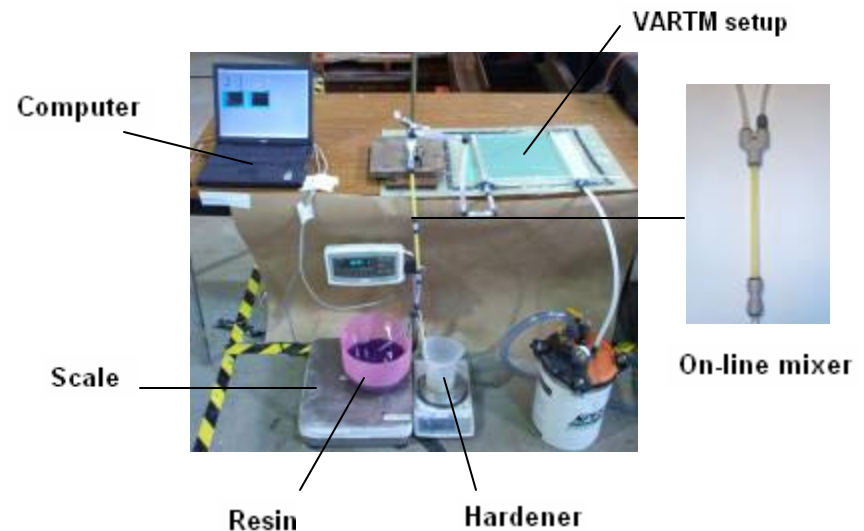


## Varying mixing ratio with injector pump



- Syringe implementation and calibration
- Uniform gel time control
- Resin curing time chart needed
- Can be also used for VARTM

## Constant mixing ratio with by-pass tubing

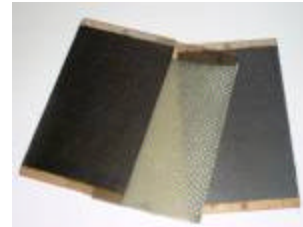


- Validation of diameters calculation
- Monitoring of the mixing ratio during injection
- Characterization of the degree of cure
- Can be also used for RTM

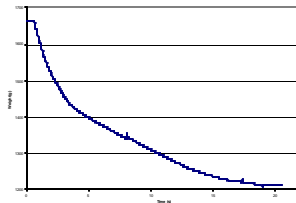
# Results



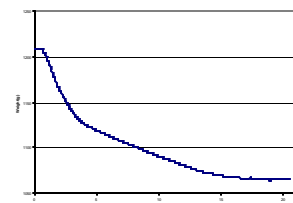
1. Wide range of mixing ratio available.
2. Several successful experiments were run using different types of resins and fibers for both RTM and VARTM processes.



3. According to DSC measures, the degree of cure obtained with this process is comparable to mechanical mixing results.
4. Mixing ratio obtained with by-pass tubing setup remains constant over time.



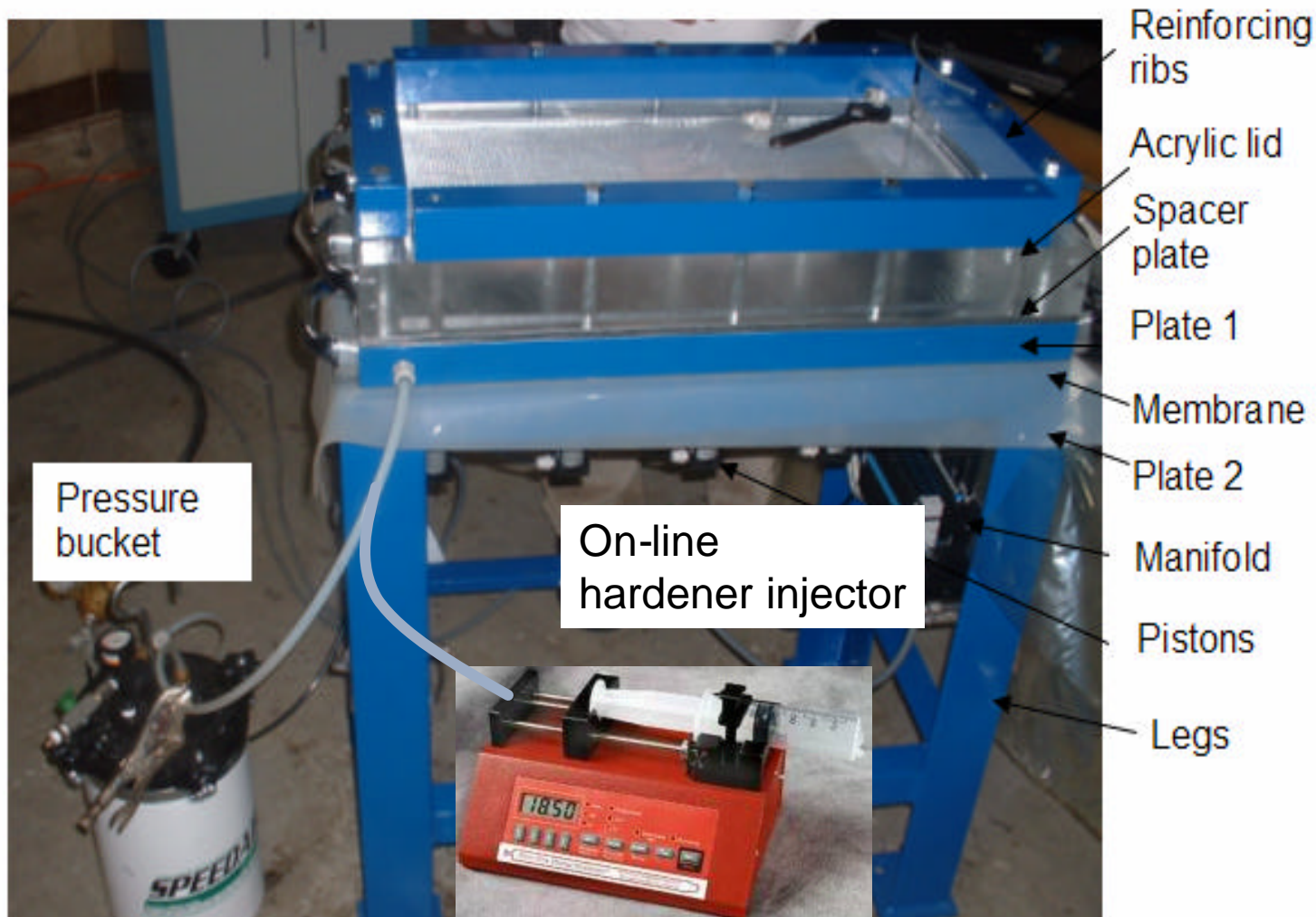
Pure resin



Hardener



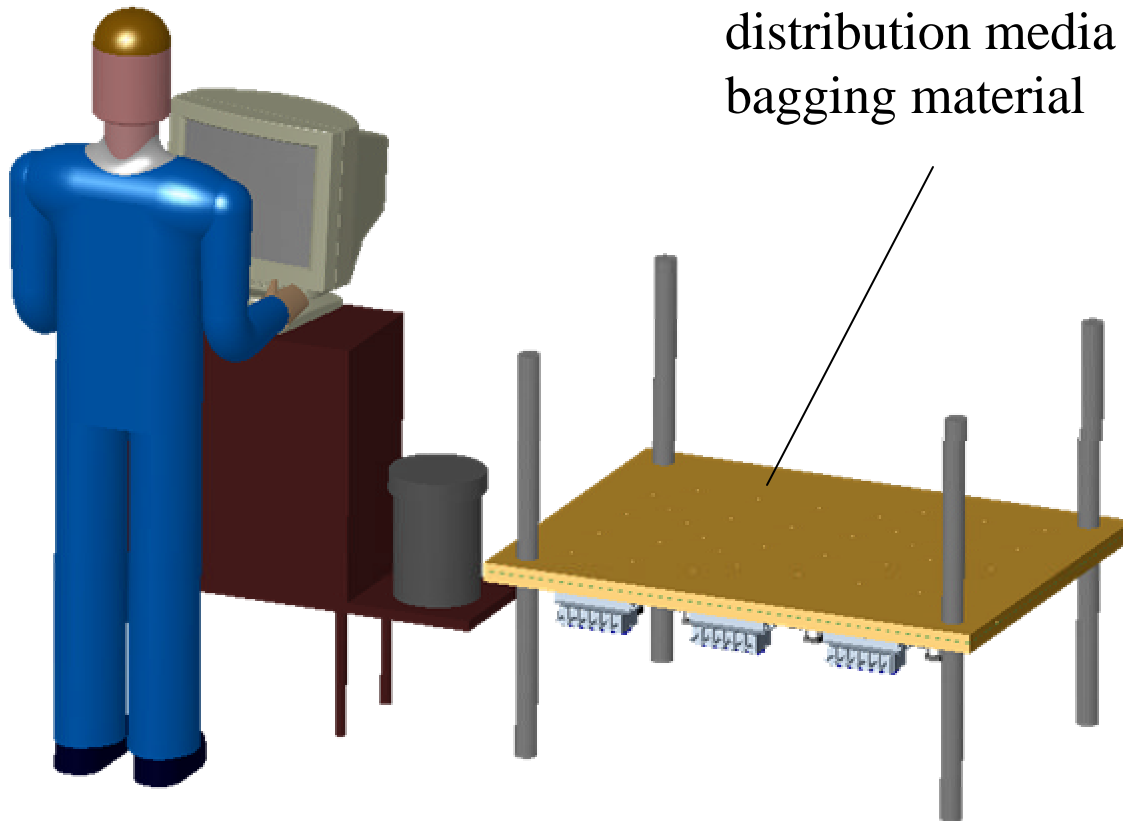
# Extension - RTM



# Extension - VARTM



Mold surface for  
preform /  
distribution media /  
bagging material



The modularity of  
the system as well  
as the injection  
system can be  
applied to  
manufacturing with  
VARTM

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# Conclusions

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- The modularity of the workstation was validated through manufacturing various part geometries
- The seamless flow of data between LIMSUI and the workstation as well as experimental automation were demonstrated with a sequential injection
- The integration between SLIC and the workstation are in the beginning stages
- On-line mixing of resin components allows for ease of resin handling during manufacturing